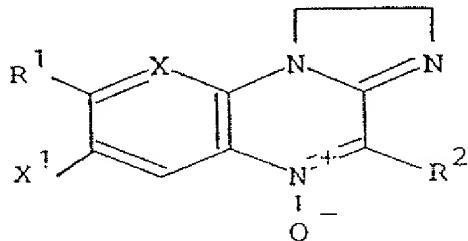


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(54) Title: NOVEL BIOREDUCTIVE AGENTS



(57) Abstract

Quinoxaline or pyrido pyrazine derivatives of formula (I) wherein R¹ is: hydrogen, alkyl, alkoxy, alkylamino, dialkylamino, aminoalkylamino, aminoalkyl(N-alkyl)amino or aminoalkoxy unsubstituted or substituted on the terminal amino group by one or two alkyl groups or a divalent group which forms a saturated heterocyclic ring together with the nitrogen atom to which it is attached, hydroxyalkylamino or haloalkylamino or an N-alkyl derivative thereof, or hydroxyalkoxy or haloalkoxy; a heterocyclic group which is a 1-pyrrolidino, 1-piperidino, 1-morpholino group, unsubstituted or substituted; or a 1-piperazino group which is unsubstituted or substituted substituents in the 2- or 3-position and in the 4-position is unsubstituted or N-substituted by haloalkyl, cycloalkyl, pyridyl or phenyl; R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted; X is -CH= or -N= ; and X¹ is hydrogen or halogen; and pharmaceutically acceptable salts thereof are useful in the treatment of tumours, and in particular hypoxic tumours. Processes for producing the compounds and pharmaceutical compositions comprising them.

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NOVEL BIOREDUCTIVE AGENTS

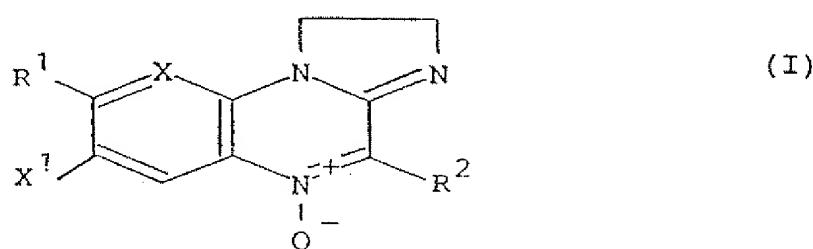
The present invention relates to dihydroimidazo-quinoxaline and dihydroimidazo-pyridopyrazines useful in the treatment of cancer. It further relates to processes 5 for their preparation and pharmaceutical compositions containing them.

EP-A-214,632 discloses quinoxaline and pyridopyrazine derivatives which are useful as anti-anaerobic agents, for the treatment of diseases related to anaerobic bacteria. 10 Such diseases include for example, post-operative sepsis following lower gastrointestinal surgery or female urinogenital surgery, pelvic inflammatory disease, ulcers, gangrene, trichomonal vaginitis, non-specific vaginitis, amoebiasis, giardiasis, periodontal disease, acne, and the 15 like.

WO-A-93/00900 which was published after both the priority dates of the present case, discloses that the compounds disclosed in EP-A-214,632 and pharmaceutically acceptable salts thereof are useful in the treatment of 20 tumours and particularly hypoxic tumours.

The present invention provides a quinoxaline or pyridopyrazine derivative of formula (I)

25



- 2 -

wherein R' is:

hydrogen, alkyl, alkoxy, alkylamino, dialkylamino, aminoalkylamino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a 5 divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino 10 unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being 15 substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkoxy unsubstituted or substituted on the amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally 20 containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino, hydroxyalkyloxy, haloalkylamino, haloalkyl(N-alkyl)amino, or haloalkyloxy;

25 a heterocyclic group which is a 1-pyrrolidino, 1-piperidino or 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or

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a 1-piperazino-group which is unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position is unsubstituted or N-substituted by haloalkyl, cycloalkyl
5 of 5 to 7 carbon atoms (unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents), or pyridyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents) or phenyl (unsubstituted or substituted by one or more
10 alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents);

R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents selected from halogen, haloalkyl, alkyl, nitro, hydroxy,
15 alkoxy and alkylenedioxy;

X is -CH= or -N=; and

X¹ is hydrogen or halogen;

wherein the said alkyl groups and moieties incorporating alkyl groups contain from 1 to 6 carbon atoms
20 and the said haloalkyl groups contain one or more halogen atoms;

or a pharmaceutically acceptable salt thereof;

with the exclusion of (a) the compounds of formula (I) where R¹ is hydrogen, X is -N=, X¹ is hydrogen and R² is
25 unsubstituted phenyl or 3-pyridyl, and R¹ is hydrogen, X is -CH=, X¹ is hydrogen and R² is 4-fluorophenyl, 3,4-dimethoxyphenyl, 3,4-ethylenedioxy or 3,4,5-trimethoxyphenyl and (b) the compound of formula (I) which is 1,2-dihydro-8-(piperazin-1-yl)-4-phenylimidazo [1,2a]

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quinoxaline 5-oxide.

According to further features the present invention provides processes for producing the compounds of the present invention and pharmaceutical compositions 5 comprising compounds of formula (I) (including exclusions (a) and (b) from the compounds of the invention).

In the compounds of formula (I), the alkyl, haloalkyl and alkoxy groups may be either straight or branched.

It is preferred that any alkyl groups in the 10 compounds of formula (I) (including alkyl groups which form part of alkoxy groups) be alkyl groups of 1 to 4 carbon atoms, i.e. methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl or tert-butyl. Particularly preferred alkyl substituents are methyl, and ethyl, most preferably methyl.

15 In the compounds of formula (I) halogen atoms present as halogen substituents or in haloalkyl substituents may for example be fluorine, chlorine or bromine atoms.

In a first embodiment the group R¹ is hydrogen or an alkyl group. Preferably R¹ is other than hydrogen.

20 In a second embodiment the group R¹ is an alkylamino, dialkylamino or alkoxy group, for example an alkylamino or dialkylamino group.

In a third embodiment the group R¹ is an 25 aminoalkylamino, aminoalkyl(N-alkyl)amino or aminoalkoxy group, substituted or unsubstituted on the terminal amino group, a hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino or hydroxyalkoxy group or a haloalkylamino, haloalkyl(N-

- 5 -

alkyl)amino or haloalkoxy group.

R¹ may for example be aminoalkylamino unsubstituted or substituted on the terminal amino group by one or two alkyl groups, amino(N-alkyl)amino unsubstituted or substituted on the terminal amino group by one or two alkyl groups, hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino, haloalkylamino, or haloalkyl(N-alkyl)amino.

Preferably when R¹ is an aminoalkylamino, aminoalkyl(N-alkyl)amino or aminoalkoxy group or a substituted derivative thereof, it is a group of formula 10 (II):-



wherein Y is -O- or -NR⁵-, preferably -NR⁵-, R³, R⁴ and R⁵ are the same or different and each is hydrogen or alkyl of 15 1 to 6 carbon atoms, preferably hydrogen or methyl, and n is 2 or 3, preferably 2. Alternatively R³ and R⁴ may, together with the nitrogen atom to which they are attached form a heterocyclic ring, preferably containing 5 to 7 atoms, such as a pyrrolidino or piperidino ring, or which 20 may contain an extra nitrogen or oxygen atom, such as a piperazino or morpholino ring. Such a ring may be unsubstituted or substituted by one or more alkyl, hydroxyl or halogen substituents and/or in the case of a heterocyclic ring containing an additional nitrogen atom 25 unsubstituted at the nitrogen atom or N-substituted by alkyl, haloalkyl, cycloalkyl of 5 to 7 carbon atoms, pyridyl or phenyl. Such N-substituents may themselves be

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unsubstituted or substituted as hereinbefore defined in relation N-substituted piperazino groups R¹.

Preferably when R¹ is a haloalkylamino, haloalkyl(N-alkyl)amino or haloalkoxy or hydroxyalkylamino
5 hydroxyalkyl(N-alkyl)amino group, or hydroxyalkoxy it is a group of formula (III):-



wherein Y¹ is -O- or -NR⁶-, preferably -NR⁶-, R⁶ is hydrogen or alkyl of 1 to 6 carbon atoms, preferably hydrogen or 10 methyl, Y² is halogen or hydroxyl, preferably hydroxyl and b is 2 or 3, preferably 2. R¹ may for example be haloalkylamino or haloalkyl(N-alkyl)amino or hydroxyalkylamino or hydroxyalkyl(N-alkyl)amino group.

In a fourth embodiment R¹ is an unsubstituted or 15 substituted, preferably unsubstituted, 1-pyrrolidino, 1-piperidino, 1-morpholino or aziridino group.
1- Morpholino groups are most preferred. When such a group is substituted it is preferably substituted by a single substituent. Preferred substituents include hydroxyl and 20 alkyl, preferably methyl or ethyl, more preferably methyl, for pyrrolidino, piperadino and morpholino groups and methyl and ethyl, more preferably methyl, for aziridino groups.

In a fifth embodiment R¹ is an unsubstituted or 25 substituted 1-piperazino group. Preferably the group is unsubstituted in the 2- and 3-positions. Where there is such substitution, there is preferably a single

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substituent, and preferred substituents include hydroxyl and alkyl, preferably methyl or ethyl, more preferably methyl.

Preferably the 1-piperazino is N-substituted in the
5 4-position by a haloalkyl, cycloalkyl, pyridyl or phenyl group.

Preferred haloalkyl substituents are fluoroalkyl substituents preferably containing more than one fluorine atom, for example 2,2,2-trifluoroethyl or trifluoromethyl,
10 preferably 2,2,2-trifluoroethyl.

Preferred cycloalkyl substituents are cyclohexyl substituents. Preferably such a cycloalkyl substituent is itself unsubstituted. When such a cycloalkyl group is substituted it is preferably substituted by a single
15 substituent and preferred substituents include hydroxyl and alkyl, preferably methyl or ethyl, more preferably methyl.

Of pyridyl or phenyl substituents, pyridyl substituents are preferred and may be 2- or 3-, preferably 2-pyridyl. Such phenyl and pyridyl groups are preferably
20 themselves unsubstituted. When such a group is itself substituted preferred substituents are as defined in relation to R² below.

In the compounds of formula (I) R² may be unsubstituted or substituted, preferably unsubstituted.
25 Hydrocarbyl aromatic groups may for example be phenyl or

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naphthyl, preferably phenyl, and heterocyclyl aromatic groups may for example be pyridyl or thiophenyl, preferably pyridyl. Most preferably R² is unsubstituted or substituted phenyl. Pyridyl groups may be 2- or 5 3-, preferably 3-, pyridyl. Naphthyl groups may be 1- or 2-, preferably 2-, naphthyl. Thiophenyl groups may be 2- or 3- thiophenyl.

Where the group R² is substituted it is preferably substituted by 1 or 2 substituents, chosen from halogen, 10 haloalkyl, alkyl, nitro, hydroxy, alkoxy and alkylenedioxy. Preferred substituents include halogen, for example fluorine, chlorine or bromine, haloalkyl, for example trifluoromethyl, nitro, and alkoxy, for example methoxy and ethoxy, preferably methoxy. Where R² is substituted 15 phenyl, preferably it is 4-substituted phenyl, more preferably 4-halophenyl and most preferably 4-fluorophenyl.

In the compounds of formula (I) X is preferably -N=.

Preferably X¹ is hydrogen.

Salts of the compounds of formula (I) may be any 20 pharmaceutically acceptable acid addition salts of the compounds of formula (I). Examples of suitable salts include, salts of inorganic acids such as chlorides, bromides, iodides, phosphates and sulphates and salts of organic acids such as acetates, citrates, lactates and 25 tartrates. Salts of inorganic acids are preferred, hydrochlorides, hydrobromides and hydroiodides are more preferred. Hydrochlorides are most preferred.

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Particular examples of the compounds of formula (I)
are:-

1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]quinoxaline 5-oxide,

1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]pyrido [3,2-e] pyrazine 5-oxide,

10 1,2-Dihydro-4-(4-fluorophenyl)imidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

15 1,2-Dihydro-8-(1-methyl-1-hydroxyethylamino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(1-aminopropyl)amino-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

25 1,2-Dihydro-8-(4-cyclohexylpiperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

- 10 -

1,2-Dihydro-8-(2-methylaziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(piperidin-1-yl)-4-phenylimidazo [1,2-a] 5 pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(4-(2,2,2-trifluoroethyl)piperazin-1-yl)imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

10 1,2-Dihydro-8-(4-(2-pyridyl)piperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

15

1,2-Dihydro-8-(piperidin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

1,2-Dihydro-8-(pyrrolidin-1-yl)-4-phenylimidazo [1,2-a] 20 quinoxaline 5-oxide,

1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

25 1,2-Dihydro-4-(3-pyridyl)-imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

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1,2-Dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

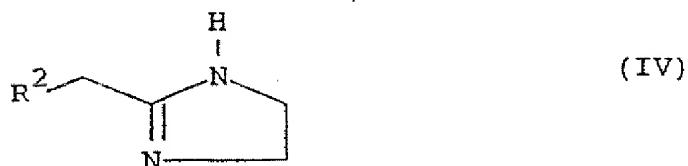
1,2-Dihydro-8-(aziridin-1-yl)-4-phenylimidazo [1,2-a] 5 pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-methoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide, and

10 1,2-Dihydro-8-(1-(dimethylamino)ethoxy)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide.

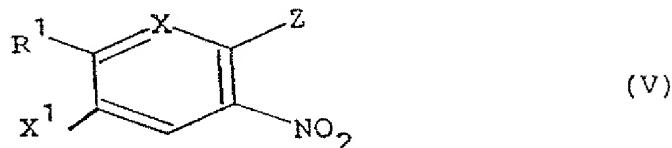
These compounds may be in the form of a free base or of salts, and in particular hydrochloride salts.

15 The compounds of formula (I) may be produced, by reacting a compound of formula (IV):



20

in which R² is as hereinbefore defined, with a compound of formula (V)



25

in which Z is halogen and R¹, X and X' are as hereinbefore defined.

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The reaction is generally carried out under basic conditions in an organic solvent as reaction medium, such as acetonitrile or an alcohol, for example 2-propanol. Generally the reaction is carried out at from 50 to 110°C, 5 preferably about 80°C.

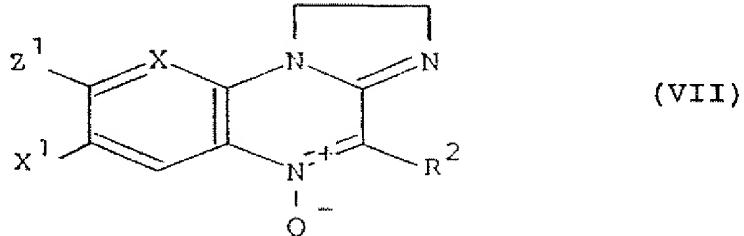
Compounds of formula (I) where R¹ is other than hydrogen or alkyl, alkoxy, unsubstituted or substituted aminoalkoxy, hydroxyalkoxy or haloalkoxy, may alternatively be produced by reacting a compound of formula (VI) :-

10



15 wherein R¹ is as hereinbefore defined with a compound of formula (VII)

20



wherein R², X and X¹ are as hereinbefore defined and Z¹ is halogen.

Generally reaction with a compound (VI) is carried out in an organic solvent, such as an alcohol, for example 25 propan-2-ol at a temperature from 60 to 110°C.

Compounds of formula (I) where R¹ is alkoxy, unsubstituted or substituted aminoalkoxy, hydroxyalkoxy or haloalkoxy may be produced by reacting a metal alkoxide, (VIA)

30



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in which R¹ is alkoxy, unsubstituted or substituted aminoalkoxy, hydroxyalkoxy or haloalkoxy, and M is a metal, for example an alkali metal, with a compound of formula (VII) as hereinbefore defined.

5 Generally reaction with an alkoxide (VIA) is performed in an alcoholic solution of alkoxide, for example in the corresponding alcohol as solvent or in methanol or ethanol, at a temperature from 50 to 80°C.

The compound of formula (I) thus obtained may be
10 purified by chromatography, for example on silica gel, or recrystallised using an appropriate solvent.

Compounds of formula (I) may be converted into pharmaceutically acceptable salts in conventional manner for the formation of acid addition salts. For example, the
15 salts of the present invention may be produced by reaction with an organic acid, or more preferably an inorganic acid such as hydrochloric acid, in an organic reaction medium.

The compounds of formulae (IV), (V), (VI), (VIA) and (VII) are compounds which may be prepared using known
20 methods. In particular compounds of formula (IV) may be obtained by reacting an acetonitrile derivative R²CH₂CN in ethylenediamine at elevated temperature, e.g. about 200°C for 24 to 48 hours. Compounds of formula (VII) may be obtained according to procedures described in EP-A-214,632.

25 The compounds of formula (I) and salts thereof are useful in increasing the sensitivity of tumour cells to

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radiation in radiotherapy and as bioreductive agents. A compound is administered to a patient having a radiation-treatable cancer, prior to or after, more typically shortly after irradiation of the tumour, in an amount effective to
5 increase the sensitivity of the tumour cells to the effects of the irradiation.

Any solid tumour, which may have regions where cells are radiobiologically hypoxic and become resistant to ionising radiation, may be treated. Examples of such
10 tumours are epithelial tumours of the head, neck, thorax and abdomen, soft tissue sarcomas and brain tumours. The compounds of formula (I) and salts thereof can therefore be employed in the radiotherapy of all such solid tumours where hypoxic cells are known or suspected to exist.

15 The compounds of formula (I) and salts thereof may also be used where an agent having differential hypoxic cytotoxicity is required. The compounds can be employed for chemopotentiation of a chemotherapeutic agent or as a
chemotherapeutic by administration of a compound to a
20 patient having a localised or metastatic cancer.

Administration is carried out prior to, simultaneously with or after administration of, typically prior to or simultaneously with, a chemotherapeutic agent such as melphalan, cyclophosphamide, 5-fluorouracil, adriamycin,
25 CCNU(1-(2-chloroethyl)-3-cyclohexyl-1-nitrosourea) or tumour necrosis factor (TNF). Any solid tumours, such as above, which are primary or secondary deposits, where it is

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known or suspected that hypoxic cells are present can therefore benefit from treatment employing a compound of formula (I) or a salt thereof.

The compounds of formula (I) and salts thereof are
5 useful in particular for the treatment of hypoxic tumours. However they may also be useful in the treatment of other tumours rich in enzymes required to activate them as bioreductive agents or radiosensitisers. Such enzymes may include cytochrome P450, NADPH dependent cytochrome P450
10 reductase, DT-diaphorase and xanthine oxidase.

The compounds of formula (I) and salts thereof may be administered orally or parenterally. The amount administered depends on factors such as the cancer, the condition of the patient and the body weight of the
15 patient. Typically, however, doses of 50 to 1000mg/m² of a patient's body area may be employed.

Accordingly, the present invention further provides a pharmaceutical composition comprising a compound of formula (I), as hereinbefore defined or a pharmaceutically acceptable salt thereof, in association with a pharmaceutically acceptable carrier or diluent.
20

The compounds of formula (I) and salts thereof may be formulated in a manner appropriate to the treatment for which it is to be used by bringing it into association with
25 a pharmaceutically acceptable carrier or diluent.

Preferably the composition is in a form suitable for parenteral administration. The compound may be included in

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a dosage form suitable for bolus injection or such as a tablet or capsule, for example a capsule comprising known formulation components. The compound may also be formulated for intravenous administration e.g. in a saline 5 drip solution.

Suitable carrier or diluent materials for inclusion in the compositions of the present invention include organic or inorganic inert carrier or diluent material for example, water, gelatin, lactose, starch, magnesium 10 stearate, talc, vegetable oils, gum arabic, polyalkylene-glycols, petroleum jelly and the like. The pharmaceutical compositions may be sterilised, pyrogen-free and isotonic. The compositions may contain adjuvants such as preserving, stabilising, wetting or emulsifying agents, salts for 15 varying the osmotic pressure or buffers. The pharmaceutical compositions may contain other therapeutically valuable substances.

The present invention further provides compounds of formula (I), as hereinbefore defined, and pharmaceutically 20 acceptable salts thereof with the exclusion of (a) the compounds of formula (I) where R¹ is hydrogen, X is -N=, X¹ is hydrogen and R² is unsubstituted phenyl or 3-pyridyl, and R¹ is hydrogen, X is -CH=, X¹ is hydrogen and R² is 4-fluorophenyl, 3,4-dimethoxyphenyl, 3,4-ethylenedioxy or 25 3,4,5-trimethoxyphenyl (but including 1,2-dihydro-8-(piperazin-1-yl)-4-phenylimidazo [1,2a] quinoxaline 5-oxide) for use in the treatment of the human or animal body

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in a method of therapy, for example treatment of a hypoxic tumour.

The invention further provides use of the compounds of formula (I) and pharmaceutically acceptable salts thereof (including compounds excluded by (a) and (b), from the compounds of the invention) in the manufacture of a medicament for use in the treatment of a tumour, for example a hypoxic tumour.

The following Examples illustrate the invention.

EXAMPLE 1

1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]quinoxaline 5-oxide.

Under an argon atmosphere, 1,2-dihydro-8-fluoro-4-phenylimidazo [1,2-a] quinoxaline 5-oxide (4.0g, 14.2 mmol) and piperazine (12.2g, 0.142 mmol) were heated at 90°C in 2-propanol (20 ml) for 3.5h. The solvent was removed under reduced pressure and the residue dissolved in CH₂Cl₂ (50 ml), washed with H₂O (50 ml)) and dried (MgSO₄) and concentrated. The resulting orange solid was recrystallised from EtOAc/CH₂Cl₂, to yield 4.2g (72%) of 1,2-dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]quinoxaline 5-oxide, mp-212-214°C (Found : C; 68.2, H; 6.0, N; 19.6%, C₂₀H₂₁N₅O.0.33H₂O requires C; 68.0, H; 6.1, N; 19.8%).

1,2-Dihydro-8-fluoro-4-phenylimidazo[1,2-a]quinoxaline 5-oxide may be prepared as disclosed in EP-A-214632.

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EXAMPLE 2

1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide.

1,2-Dihydro-8-chloro-4-phenylimidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide (0.1g, 0.335 mmol) and piperazine (0.288g, 3.35 mmol) were heated at 60°C in 2-propanol for 0.5h under an argon atmosphere. The solution was cooled, evaporated and redissolved in 50ml CH₂Cl₂, washed with H₂O (50 ml), dried and evaporated to afford, after recrystallisation from EtOAc/CHCl₃, 1,2-dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide (72%) as an orange solid, mp=177-178°C (Found : C; 64.7, H; 5.7, N; 23.8%, C₁₉N₂₀N₆O.0.33H₂O requires C; 64.4, H; 5.8, N; 23.7%)

The product was converted to a bis-hydrochloride by reaction with 2.2 equivalents of HCl, using the procedure described in Example 4, (m.p.: greater than 250°C).

1,2-Dihydro-8-chloro-4-phenylimidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide may be prepared as disclosed in EP-A-214632.

EXAMPLE 3

1,2-Dihydro-4-(4-fluorophenyl)imidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide.

A mixture of 2-chloro-3-nitropyridine (0.44g, 2.8 mmol) and 2-(4-fluorobenzyl)-2-imidazoline (0.5g, 2.79 mmol) in CH₃CN (8 ml) was heated at 80°C for 12 h in a

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nitrogen atmosphere. The solution was then left at room temperature overnight, evaporated and the residue purified on silica (MeOH/EtOAc, 1:10) to give 0.38g (48%) of 1,2-dihydro-4-(4-fluorophenyl)imidazo[1,2-a] pyrido [3,2-e] 5 pyrazine 5-oxide after recrystallisation from MeOH, mp=213-215°C, ¹H-NMR (CDCl₃) δ 4.1 (s, 4H), 6.8 (dd, 1H, J=8 and 8Hz), 7.0 (d, 2H, J=9.6Hz), 7.9 (d, 2H, J=9.6Hz) and 8.2 (m, 2H) ppm.

EXAMPLE 4

10 1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide bishydrochloride

8-Chloro-1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (1.0g, 3.36 mmol) and N,N,N'-trimethylethylenediamine (3.4g, 33.6 mmol) were heated at 90°C in 2-propanol (5 ml) for 3.5h. The solution was then evaporated and the residue purified on silica (MeOH/CH₂Cl₂, 1:10) to afford an orange foam (65%), of which 437 mg (1.0 mmol) was redissolved in 4 ml EtOAc/CH₂Cl₂ (1:1), and 2.2ml of a 1.0M solution of HCl in Et₂O, filtered and washed again with cold Et₂O to give 1,2-dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide bishydrochloride mp=205-208°C (dec.) ¹H-NMR (CDCl₃) 2.3 (s, 6H) 2.5 (t, 2H, J=7.2Hz), 3.1 (s, 3H), 3.75 (t, 2H, J=7.2Hz), 4.1 (s, 4H), 6.1 (d, 1H, J=8.4 Hz), 7.4 (m, 3H), 7.8 (m, 2H) and 8.05 (d, 1H, J=8.4Hz) ppm. (Found : C; 49.7, H; 6.4, N; 17.0%,

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$C_{20}H_{24}N_6O \cdot 2HCl \cdot 2.5H_2O$ requires C; 49.8, H; 6.3, N; 17.4%)

EXAMPLE 5

1,2-Dihydro-8-(1-methyl-1-hydroxyethylamino)-4-
5 phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide
hydrochloride

This compound was prepared in accordance with the procedure of Example 4 using 2-(methylamino)ethanol as nucleophile and with a reaction time of 1.5h and converted 10 to a hydrochloride to afford 1,2-dihydro-8-(1-methyl-1-hydroxyethylamino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide hydrochloride (63%) as a yellow solid, mp=228-230°C (dec.) (Found : C; 57.8, H; 5.3, N; 18.9%, $C_{18}H_{19}N_5O_2 \cdot HCl$ requires C; 57.8, H; 5.3, N; 18.7%).

15

EXAMPLE 6

1,2-Dihydro-8-(1-aminopropyl)amino-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

This compound was prepared in accordance with the 20 procedure of Example 4 above using 1,3-diaminopropane as nucleophile and a reaction time of 1.5h. The residue after evaporation was triturated with EtOAc and the solid filtered and recrystallised from EtOAc to afford 1,2-dihydro-8-(1-aminopropyl)amino-4-phenylimidazo [1,2-a] 25 pyrido [3,2-e] pyrazine 5-oxide (57%) as orange crystals, mp=179-180°C (Found : C; 62.4, H; 6.0, N; 24.4%, $C_{18}H_{20}N_6O \cdot 0.5H_2O$ requires C; 62.6, H; 6.1, N; 24.4%).

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EXAMPLE 7

1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide bishydrochloride

This compound was prepared in accordance with the procedure of Example 4 above at 80°C for 2.5h using morpholine as the nucleophile, and the orange crystals which appeared upon cooling were filtered, washed with EtOH and recrystallised from 2-propanol, and converted to the hydrochloride using the procedure described above to yield 1,2-dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide bishydrochloride (74%), mp=224-226°C, (Found, C; 54.3, H; 5.3, N; 16.6%, C₁₉H₁₉N₅O₂.2HCl requires C; 54.0, H; 5.0, N; 16.6%).

15 EXAMPLE 8

1,2-Dihydro-8-(4-cyclohexylpiperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

This compound was prepared in accordance with the procedure of Example 4 above using 4-cyclohexylpiperazine as the nucleophile, and the orange crystals formed on cooling were collected and washed with 2-propanol. The product was recrystallised from 2-propanol to afford 1,2-dihydro-8-(4-cyclohexylpiperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (78%), mp=188-189°C, (Found : C; 69.7, H; 7.0, N; 19.5%, C₂₅H₃₀N₆O requires C; 69.8, H; 7.0, N; 19.5%).

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EXAMPLE 9

1,2-Dihydro-8-(2-methylaziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

8-Chloro-1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (0.25g, 0.84 mmol) was dissolved in 1.5 ml benzene and 0.3 ml Et₃N, and 2-methylaziridine (0.2g, 3.5 mmol) were added and the solution stirred at 70-80°C for 1.5h. The solution was cooled and evaporated and the residue purified on silica (MeOH/CH₂Cl₂, 1:10) to afford 1,2-dihydro-8-(2-methylaziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (42%) as an orange waxy solid. The compound was analysed as the ring-opened hydrobromide, prepared by treating with 48% HBr in Me₂CO, filtering and washing with cold Me₂CO to give the ring-opened monohydrobromide, mp=200-201°C (dec.), (Found : C; 45.2, H; 4.1, N; 14.6%, C₁₈H₁₈N₅OBr.HBr requires C; 44.9, H; 4.0, N; 14.6%).

EXAMPLE 10

1,2-Dihydro-8-(piperidin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

This compound was prepared in accordance with the reaction conditions described for Example 4, using piperidine as nucleophile and at a reaction temperature of 60°C for 0.5h. Recrystallisation from 2-propanol afforded 1,2-dihydro-8-(piperidin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (68%) as an orange solid,

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mp=185-187°C (Found : C; 69.1, H; 6.1, N; 20.2%, C₂₀H₂₁N₅O requires C; 69.2, H; 6.1, N; 20.2%).

EXAMPLE 11

5 1,2-Dihydro-8-(4-(2,2,2-trifluoroethyl)piperazin-1-yl)imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

This compound was prepared in accordance with the procedure of Example 4, using N-(2,2,2-trifluoroethyl)piperazine as nucleophile to afford 1,2-dihydro-8-(4-(2,2,2-trifluoroethyl)piperazin-1-yl)imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (68%) as an orange solid after recrystallisation from ethanol, mp=221-222°C (Found : C; 58.7, H; 4.9, N; 19.6%, C₂₁H₂₁N₆OF, required C; 58.6, H; 4.9, N; 19.5%).

15

EXAMPLE 12

1,2-Dihydro-8-(4-(2-pyridyl)piperazine-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

This compound was prepared in accordance with the procedure of Example 4, except that the cooled reaction mixture was left at -18°C for 1h, and the orange crystals filtered and washed with 2-propanol to yield, after recrystallisation from 2-propanol, 1,2-dihydro-8-(4-(2-pyridyl)piperazine-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (55%), mp=201.5-202.5°C, ¹H-NMR (CDCl₃) δ 3.8 (m,8H), 4.2 (s,4H), 6.3 (d,1H,J=8.4Hz), 6.75 (m,2H), 7.4 (m,3H), 7.8 (m,3H), 8.3 (m,1H), 8.35

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(d, 1H, J=8.4Hz) ppm.

The product was converted to a bishydrochloride as described for Example 4, mp=232-235°C (dec.)

5 EXAMPLE 13

1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide

1,2-Dihydro-8-fluoro-4-phenylimidazo [1,2-a] quinoxaline 5-oxide (0.5g, 1.54 mmol) in 5 ml 2-propanol, 10 was heated at 100°C for 8h with morpholine (1.5 ml, ca. 16.8 mmol). The solution was then cooled and evaporated, and the residue purified on silica gel, eluting with EtOAc/MeOH (5:1), to yield 1,2-dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide (65%) as an 15 orange solid, mp=232-233°C (dec.)

The product was converted to a monohydrochloride as described for Example 4 using 1.1 equivalents of HCl.

EXAMPLE 14

20 **1,2-Dihydro-8-(pipiridin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide**

This compound was prepared in accordance with the procedure of Example 13 to afford 1,2-dihydro-8-(pipiridin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide (71%) as 25 an orange solid, mp=230-231°C (dec.), monohydrochloride mp=246-247°C (dec.) $^1\text{H-NMR}$ (CDCl_3) δ 1.8 (m, 6H), 3.4 (m, 4H), 4.05 (s, 4H), 6.0 (d, 1H, J=2.4Hz), 6.5 (dd, 1H, J=2.4 and

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9.6Hz), 7.3 (m,3H), 7.8 (m,2H) and 8.0 (d,1H,J=8.4Hz) ppm.

EXAMPLE 15

1,2-Dihydro-8-(pyrrolidin-1-yl)-4-phenylimidazo [1,2-a]

5 **quinoxaline 5-oxide**

This compound was prepared in accordance with the procedure of Example 13, to afford, as an orange solid, 1,2-dihydro-8-(pyrrolidin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide, mp=246-247°C (dec.), monohydrochloride 10 mp>=275°C (dec.) $^1\text{H-NMR}$ δ 2.0 (m,4H), 3.35 (m,4H), 4.0 (s,4H), 5.6 (d,1H,J=2.4Hz), 6.2 (dd,1H,J=2.4 and 9.6Hz), 7.3 (m,3H), 7.75 (m,2H) and 8.0 (d,1H,J=8.4Hz) ppm.

EXAMPLE 16

15 **1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide bishydrochloride**

1,2-Dihydro-8-fluoro-4-phenylimidazo [1,2-a] quinoxaline 5-oxide (0.5g, 1.7 mmol) and N,N,N'-trimethylethylenediamine (1.7g, ca.17 mmol) were heated at 20 95°C for 24h, cooled and evaporated. The residue was purified on silica gel eluting with 10% MeOH/CH₂Cl₂ to afford an orange waxy solid (62%), which was converted into the bishydrochloride as described in Example 4 to give 1,2-dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide bishydrochloride, 25 mp>= 250°C (dec.) $^1\text{H-NMR}$ (CDCl₃) δ 2.3 (s,6H), 2.6 (t,2H,J=7.2Hz), 3.05 (s,3H), 3.5 (t,2H,J=7.2Hz), 4.0

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(s, 4H), 5.8 (d, 1H, J=2.4Hz), 6.4 (dd, 1H, J=2.4 and 9.6Hz),
7.35 (m, 3H), 7.7 (m, 2H), and 8.0 (d, 1H, J=8.4Hz) ppm.

EXAMPLE 17

5 **1,2-Dihydro-4-(3-pyridyl)-imidazo [1,2-a] pyrido [3,2-e]**
pyrazine 5-oxide

2-Chloro-3-nitropyridine (0.22g, 1.4 mmol) and 2-(3-pyridyl)methyl-imidazoline (0.23g, 1.42 mmol) were heated at 85°C in acetonitrile for 4.5h. The solution was cooled, 10 evaporated and the residue purified on silica, eluting with EtOAc/MeOH (10:1) to yield 1,2-dihydro-4-(3-pyridyl)-imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (50%) as deep yellow crystals after recrystallisation from EtOAc, mp=128-130°C, monohydrochloride mp=214-216°C (dec.) ¹H-NMR
15 δ 3.6 (s, 2H), 3.8 (s, 2H), 6.7 (dd, 1H, J=4.8 and 9.6Hz), 7.3 (m, 1H), 7.6 (m, 1H) and 8.4 (m, 4H) ppm.

EXAMPLE 18

1,2-Dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine
20 **5-oxide hydrochloride**

This compound was prepared in accordance with the procedure of Example 17 using tolazoline in place of 2-(3-pyridyl)methyl-imidazoline and with a reaction time of 12h. Deep yellow crystals of the free base were obtained (63%) and recrystallised from MeOH, mp=194-195°C ¹H-NMR (CDCl₃) δ 25 3.6 (s, 2H) 3.9 (s, 2H), 6.6 (dd, 1H, J=8 and 8Hz) and 8.3 (m, 2H) ppm. This material was converted into the

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monohydrochloride salt as described in Example 4, using 1.1 equivalents of HCl, to afford, as a yellow solid, 1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide hydrochloride, mp=238-240°C (dec.).

5

EXAMPLE 19

1,2-Dihydro-8-(aziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

8-Chloro-1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (1.0g, 3.36 mmol) was stirred with aziridine 3.5g (81.4 mmol) at 25°C for 2h. The excess aziridine was evaporated at room temperature and the residue purified on silica eluting with ethyl acetate: triethylamine (99:1) to afford 1,2-dihydro-8-(aziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide as a deep yellow solid, recrystallised from ethyl acetate mp = 168-170°C, ¹H-NMR (CDCl₃) δ 2.2 (s, 4H), 4.0 (bs, 4H), 6.4 (d, 1H, J=8.4Hz), 7.2 (m, 3H), 7.6 (m, 2H), and 8.0 (d, 1H, J=8.4Hz) ppm. (Found: C; 66.8, H; 4.6, N; 22.7%, C₁₇H₁₅N₅O requires C; 66.9, H; 4.9, N; 22.9%).

EXAMPLE 20

1,2-Dihydro-8-methoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide

25 A solution of sodium methoxide in methanol (25%, 1mL) was stirred at room temperature together with 8-chloro-1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-

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oxide (0.1g, 0.34 mmol) for 2 hours. The solution was then heated for 1 hour at 80°C, cooled and water (1mL) added. The solution was evaporated, and redissolved in chloroform (25mL), then washed with water (25mL). The organic layer 5 was dried and evaporated, and the residue purified on silica gel, eluting with ethyl acetate/hexane (1:1) to afford 1,2-dihydro-8-methoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (75mg, 75%) as an orange solid which was recrystallised from mp 194-195°C. The product 10 was converted to a monohydrochloride using the method described in Example 4, mp 223-224°C(dec.). Found: C; 64.8, H; 4.8, N; 19.2%, $C_{16}H_{14}N_4O_2$ requires C; 65.3, H; 4.8, N; 19.0%.

EXAMPLE 21

15 1-2-Dihydro-8-(1-dimethylamino)ethoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide
 8-Chloro-1,2-dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide (1.0g, 3.4 mmol) was added slowly to a cooled solution of sodium N,N-dimethylethanamine 20 (6mL, 30% in N,N-dimethylethanamine) and the solution stirred at room temperature for 12 hours, followed by 2 hours at 50°C. Water (50mL) was added and the solution extracted with ethyl acetate (3x100mL), dried and evaporated. The residue was purified on silica, eluting 25 with ethyl acetate: methanol: ammonium hydroxide (47.5:47.5:5) to afford 1-2-dihydro-8-(1-dimethylamino)ethoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e]

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pyrazine 5-oxide as an orange solid (0.7g, 69%)
recrystallised from ethyl acetate:methanol, mp 158-161°C,
(Found C; 61.0, H; 5.9, N; 18.8%, C₁₉H₂₁N₅O₂ 1.25 H₂O requires
C; 61.0, H; 6.3, N; 18.7%)

5 **EXAMPLE 22**

The toxicity of compounds prepared in the foregoing Examples towards aerobic or hypoxic V79 Chinese hamster cells in vitro is shown in Table 1. Toxicity was determined by the use of the modified MTT assay (Stratford 10 and Stephens (1989), Int. J. Radiat. Oncol. Biol. Phys. 16 973-976). Values quoted represent concentration of drug required to reduce proliferation of treated cultures by 50%. Cells are treated with various drug doses for 3 hours at 37°C under aerobic or hypoxic conditions, following drug 15 removal cells are allowed to proliferate for 3 days prior to assay.

TABLE 1

	Compound	C air	C N ₂	Ratio
		mmol dm ⁻³		
20	Example 1*	0.2	0.03	6.7
	Example 2	0.45	0.045	10
25	Example 4	0.45	0.06	7.5
	Example 7	0.5	0.2	2.5
	Example 8	0.45	0.045	10
30	Example 12*	1.0	0.1	10
	Example 13	2.4	0.55	4.4
	Example 18	5.0	0.6	8.3
	Example 20	12.0	0.7	17.0
35	Example 21*	2.5	0.05	50

* tested as free base.

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EXAMPLE 23

C3H mice in which the transplantable rodent tumour RIF-1 had been implanted subcutaneously were administered the compound of Example 2 (hydrochloride salt) [100 mg/kg] 5 intraperitoneally immediately after irradiation with 25 Gy X-rays. The time for the tumour to increase in size to four times its original volume was 44 days compared with the corresponding time where no treatment was applied to the tumour (5 days) and where the tumour was treated by 10 irradiation with 25 Gy X-rays alone (35 days).

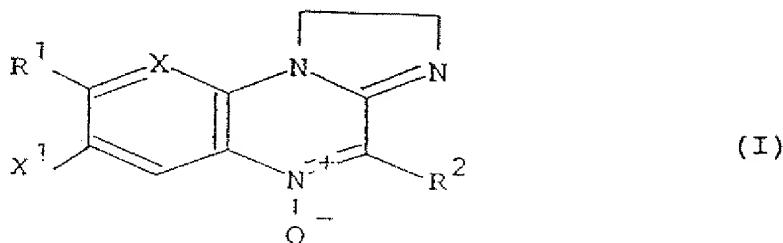
The results show that the use of the compound immediately after irradiation to kill viable cells which were hypoxic at the time of irradiation, leads to a significant slowing in the growth of the tumour.

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CLAIMS

1. A quinoxaline or pyridopyrazine derivative of formula (I)

5



wherein R¹ is:

10 hydrogen, alkyl, alkoxy, alkylamino, dialkylamino, aminoalkylamino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms 20 a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkoxy unsubstituted or substituted on the amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen

25

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substituents, hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino, hydroxyalkyloxy, haloalkylamino, haloalkyl(N-alkyl)amino, or haloalkyloxy;

a heterocyclic group which is a 1-pyrrolidino, 1-5 piperidino, 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or
a 1-piperazino group which is unsubstituted or 10 substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position is unsubstituted or N-substituted by haloalkyl, cycloalkyl of 5 to 7 carbon atoms (unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents), or pyridyl 15 (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents) or phenyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents);

20 R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents selected from halogen haloalkyl, alkyl, nitro, hydroxy alkoxy and alkylenedioxy;

X is -CH= or -N=; and

25 X¹ is hydrogen or halogen;

wherein the said alkyl groups and moieties incorporating alkyl groups contain from 1 to 6 carbon atoms

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and the said haloalkyl groups contain one or more halogen atoms;

or a pharmaceutically acceptable salt thereof;

with the exclusion of (a) the compounds of formula

5 (I) where R¹ is hydrogen, X is -N=, X¹ is hydrogen and R² is unsubstituted phenyl or 3-pyridyl, and R¹ is hydrogen, X is -CH=, X¹ is hydrogen and R² is 4-fluorophenyl, 3,4-dimethoxyphenyl, 3,4-ethylenedioxy- or 3,4,5-trimethoxyphenyl and (b) the compound of formula (I) which
10 is 1,2-dihydro-8-(piperazin-1-yl)-4-phenylimidazo [1,2a] quinoxaline 5-oxide.

2. A compound according to claim 1 wherein R¹ is:

hydrogen, alkyl, alkylamino, dialkylamino, aminoalkylamino unsubstituted or substituted on the
15 terminal amino group by one or two alkyl groups, aminoalkyl(N-alkyl)amino unsubstituted or substituted on the terminal amino group by one or two alkyl groups, hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino, haloalkylamino, haloalkyl(N-alkyl)amino;
20 a heterocyclic group which is a 1-pyrrolidino, 1-piperidino, 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or
25 a 1-piperazino group which is unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position

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is unsubstituted or N-substituted by haloalkyl, cycloalkyl of 5 to 7 carbon atoms (unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents), or pyridyl (unsubstituted or substituted by one or more alkyl,
5 haloalkyl, hydroxy, alkoxy, nitro or halogen substituents) or phenyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents); and

R² is phenyl or pyridyl unsubstituted or substituted
10 by one or more substituents selected from halogen haloalkyl, alkyl, nitro, hydroxy alkoxy and alkylenedioxy;

3. A compound according to claim 1 or 2 in which R¹ is other than hydrogen.

4. A compound according to claim 1, 2 or 3 in
15 which the group R¹ is aminoalkylamino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen
20 or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together
25 with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom, and optionally being substituted by one or more alkyl,

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hydroxyl or halogen substituents, aminoalkoxy unsubstituted or substituted on the amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to 5 which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents,
hydroxyalkylamino, hydroxyalkyl(N-alkyl)amino,
hydroxyalkyloxy, haloalkylamino, haloalkyl(N-alkyl)amino,
10 or haloalkyloxy.

5. A compound according to claim 4 in which R¹ is a group of formula (II)



wherein Y is -O- or -NR⁵-, R³, R⁴ and R⁵ are the same or 15 different and each is hydrogen or alkyl of 1 to 6 carbon atoms or form a heterocyclic ring containing from 5 to 7 carbon atoms, together with the amino nitrogen atom to which they are attached and optionally a further nitrogen or oxygen atom and a is 2 or 3;
20 or R¹ is a group of formula (III)



wherein Y¹ is -O- or -NR⁶-, R⁶ is hydrogen or alkyl of 1 to 6 carbon atoms, Y² is halogen or hydroxyl, and b is 2 or 3.

6. A compound according to claim 1, 2 or 3 in
25 which R¹ is unsubstituted or substituted 1-pyrrolidino, 1-

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piperidino, 1-morpholino or aziridino.

7. A compound according to claim 1, 2 or 3 in which R¹ is a 1-piperazino group N-substituted in the 4-position by haloalkyl, cycloalkyl, pyridyl or phenyl.

5 8. A compound according to any one of the preceding claims in which R² is substituted or unsubstituted phenyl.

9. A compound according to claim 8 in which R² is unsubstituted phenyl or 4-halophenyl.

10 10. A compound according to any one of the preceding claims in which X is -N=.

11. A compound according to any one of the preceding claims in which X¹ is hydrogen.

15 12. A compound according to claim 1 which is:

1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]quinoxaline 5-oxide,

20 1,2-Dihydro-8-(piperazin-1-yl)-4-phenylimidazo[1,2-a]pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-4-(4-fluorophenyl)imidazo[1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

25 1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

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1,2-Dihydro-8-(1-methyl-1-hydroxyethylamino)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

5 1,2-Dihydro-8-(1-aminopropyl)amino-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

10 1,2-Dihydro-8-(4-cyclohexylpiperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

15 1,2-Dihydro-8-(2-methylaziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-(piperidin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

20 1,2-Dihydro-8-(4-(2,2,2-trifluoroethyl)piperazin-1-yl)imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

25 1,2-Dihydro-8-(4-(2-pyridyl)piperazin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

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1,2-Dihydro-8-(morpholin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

5 1,2-Dihydro-8-(pipiridin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

1,2-Dihydro-8-(pyrrolidin-1-yl)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

10 1,2-Dihydro-8-(1-methyl-1-(N,N-dimethylaminoethyl)amino)-4-phenylimidazo [1,2-a] quinoxaline 5-oxide,

15 1,2-Dihydro-4-(3-pyridyl)-imidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

20 1,2-Dihydro-8-(aziridin-1-yl)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide,

1,2-Dihydro-8-methoxy-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide, or

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1,2-Dihydro-8-(1-(dimethylamino)ethoxy)-4-phenylimidazo [1,2-a] pyrido [3,2-e] pyrazine 5-oxide;

5 or a pharmaceutically acceptable salt thereof.

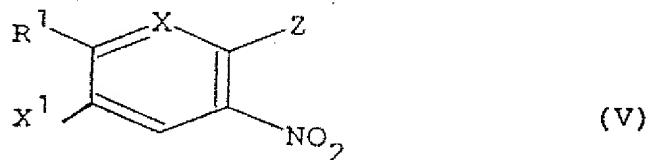
13. A process for producing a compound as claimed in any one of the preceding claims which comprises:
reacting a compound of formula (IV):-

10



wherein R² is as defined in claim 1, with a compound of formula (V):-

15



wherein Z is halogen, and R¹, X and X¹ are as defined in claim 1; or

20 where R¹ is other than hydrogen, alkyl, alkoxy, unsubstituted or substituted aminoalkoxy, hydroxyalkoxy or haloalkoxy, reacting a compound of formula (VI):-



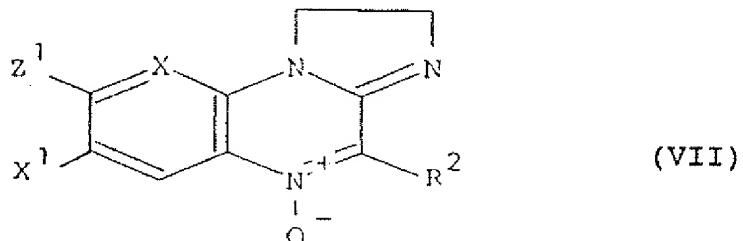
25

in which R¹ is as defined in claim 1 and is other than hydrogen, alkyl, unsubstituted or substituted aminoalkoxy,

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hydroxyalkoxy or haloalkoxy, with a compound of formula

(VII) :-



5

in which Z¹ is halogen and X, X¹ and R² are as defined in claim 1; or

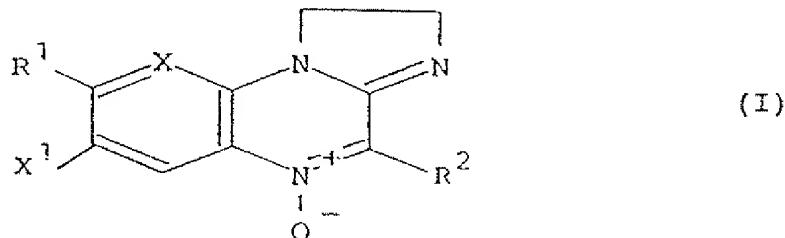
where R¹ is alkoxy, unsubstituted or substituted aminoalkoxy, hydroxyalkoxy or haloalkoxy reacting a metal 10 alkoxide (VIA)

R¹ -M

(VIA)

in which R¹ is alkoxy, unsubstituted or substituted 15 aminoalkoxy, hydroxyalkoxy or haloalkoxy, and M is a metal, with a compound of formula (VII) as hereinbefore defined; and optionally, converting the compound of formula (I) thus obtained to a pharmaceutically acceptable salt thereof.

20 14. A pharmaceutical composition which comprises a quinoxaline or pyridopyrazine derivative of formula (I)



25 wherein R¹ is

hydrogen, alkyl, alkoxy, alkylamino, dialkylamino, aminoalkylamino unsubstituted or substituted on the

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terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino unsubstituted or substituted on the terminal amino group by one or two alkyl groups or by a divalent group which forms a saturated heterocyclic ring together with the amino 5 nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkoxy unsubstituted or substituted on the amino group by one or two alkyl groups or by a divalent 10 which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkylamino, hydroxyalkyl(N- 15 alkyl)amino, hydroxyalkyloxy, haloalkylamino, haloalkyl(N-alkyl)amino, or haloalkyloxy;

a heterocyclic group which is a 1-pyrrolidino, 1-piperidino, 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen 20 substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or 25 a 1-piperazino group which is unsubstituted or

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substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position is unsubstituted or N-substituted by haloalkyl, cycloalkyl of 5 to 7 carbon atoms (unsubstituted or substituted by one 5 or more alkyl, hydroxy or halogen substituents), or pyridyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents) or phenyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen 10 substituents);

R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents selected from halogen haloalkyl, alkyl, nitro, hydroxy alkoxy and alkyleneoxy;

15 X is -CH= or -N=; and

X¹ is hydrogen or halogen;

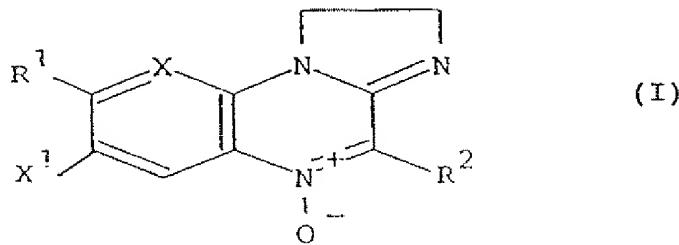
wherein the said alkyl groups and moieties incorporating alkyl groups contain from 1 to 6 carbon atoms and the said haloalkyl groups contain one or more halogen 20 atoms;

or a pharmaceutically acceptable salt thereof;

in association with a pharmaceutically acceptable carrier or diluent.

15. A quinoxaline or pyridopyrazine derivative for 25 use in the treatment of the human or animal body in a method of therapy, which is of formula (I)

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5 wherein R¹ is:

hydrogen, alkyl, alkoxy, alkylamino, dialkylamino,
aminoalkylamino unsubstituted or substituted on the
terminal amino group by one or two alkyl groups or by a
divalent group which forms a saturated heterocyclic ring
10 together with the amino nitrogen atom to which it is
attached optionally containing a further oxygen or nitrogen
atom and optionally being substituted by one or more alkyl,
hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino
unsubstituted or substituted on the terminal amino group by
15 one or two alkyl groups or by a divalent group which forms
a saturated heterocyclic ring together with the amino
nitrogen atom to which it is attached optionally containing
a further oxygen or nitrogen atom and optionally being
substituted by one or more alkyl, hydroxyl or halogen
20 substituents, aminoalkoxy unsubstituted or substituted on
the amino group by one or two alkyl groups or by a divalent
which forms a saturated heterocyclic ring together with the
amino nitrogen atom to which it is attached optionally
containing a further oxygen or nitrogen atom and optionally
25 being substituted by one or more alkyl, hydroxyl or halogen
substituents, hydroxyalkylamino, hydroxyalkyl(N-
alkyl)amino, hydroxyalkyloxy, haloalkylamino, haloalkyl(N-

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alkyl)amino, or haloalkyloxy;

a heterocyclic group which is a 1-pyrrolidino, 1-piperidino, 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or

5 a 1-piperazino group which is unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position
10 is unsubstituted or N-substituted by haloalkyl, cycloalkyl of 5 to 7 carbon atoms (unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents), or pyridyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents)
15 or phenyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents);

R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents
20 selected from halogen haloalkyl, alkyl, nitro, hydroxy alkoxy and alkylenedioxy;

X is -CH= or -N=; and

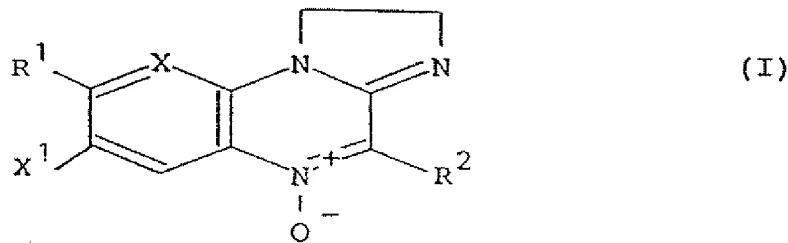
X' is hydrogen or halogen;

wherein the said alkyl groups and moieties
25 incorporating alkyl groups contain from 1 to 6 carbon atoms and the said haloalkyl groups contain one or more halogen atoms;

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or a pharmaceutically acceptable salt thereof;
 with the exclusion of (a) the compounds of formula
 (I) where R¹ is hydrogen, X is -N=, X¹ is hydrogen and R² is
 unsubstituted phenyl or 3-pyridyl, and R¹ is hydrogen, X is
 5 -CH=, X¹ is hydrogen and R² is 4-fluorophenyl, 3,4-
 dimethoxyphenyl, 3,4-ethylenedioxy- or 3,4,5-
 trimethoxyphenyl.

16. Use in the manufacture of a medicament for use
 in the treatment of a tumour of a quinoxaline or pyrido-
 10 pyrazine derivative of formula (I)



15 wherein R¹ is:

hydrogen, alkyl, alkoxy, alkylamino, dialkylamino,
 aminoalkylamino unsubstituted or substituted on the
 terminal amino group by one or two alkyl groups or by a
 divalent group which forms a saturated heterocyclic ring
 20 together with the amino nitrogen atom to which it is
 attached optionally containing a further oxygen or nitrogen
 atom and optionally being substituted by one or more alkyl,
 hydroxyl or halogen substituents, aminoalkyl(N-alkyl)amino
 unsubstituted or substituted on the terminal amino group by
 25 one or two alkyl groups or by a divalent group which forms
 a saturated heterocyclic ring together with the amino
 nitrogen atom to which it is attached optionally containing

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a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, aminoalkoxy unsubstituted or substituted on the amino group by one or two alkyl groups or by a divalent 5 which forms a saturated heterocyclic ring together with the amino nitrogen atom to which it is attached optionally containing a further oxygen or nitrogen atom and optionally being substituted by one or more alkyl, hydroxyl or halogen substituents, hydroxyalkylamino, hydroxyalkyl(N-10 alkyl)amino, hydroxyalkyloxy, haloalkylamino, haloalkyl(N-alkyl)amino, or haloalkyloxy;

a heterocyclic group which is a 1-pyrrolidino, 1-piperadino, 1-morpholino group, unsubstituted or substituted by one or more alkyl, hydroxy or halogen 15 substituents, or an aziridino group unsubstituted or substituted by one or more alkyl substituents; or a 1-piperazino group which is unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents in the 2- or 3- position and in the 4-position 20 is unsubstituted or N-substituted by haloalkyl, cycloalkyl of 5 to 7 carbon atoms (unsubstituted or substituted by one or more alkyl, hydroxy or halogen substituents), or pyridyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents), or pyridyl 25 or phenyl (unsubstituted or substituted by one or more alkyl, haloalkyl, hydroxy, alkoxy, nitro or halogen substituents);

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R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents selected from halogen haloalkyl, alkyl, nitro, hydroxy, alkoxy and alkylenedioxy;

5 X is -CH= or -N=; and

X¹ is hydrogen or halogen;

wherein the said alkyl groups and moieties incorporating alkyl groups contain from 1 to 6 carbon atoms and the said haloalkyl groups contain one or more halogen 10 atoms;

or a pharmaceutically acceptable salt thereof.

R² is a hydrocarbyl or heterocyclyl aromatic group unsubstituted or substituted by one or more substituents selected from halogen haloalkyl, alkyl, nitro, hydroxy, 15 alkoxy and alkylenedioxy;

X is -CH= or -N=; and

X¹ is hydrogen or halogen;

wherein the said alkyl groups and moieties incorporating alkyl groups contain from 1 to 6 carbon atoms 20 and the said haloalkyl groups contain one or more halogen atoms;

or a pharmaceutically acceptable salt thereof.

A. CLASSIFICATION OF SUBJECT MATTER		
IPC 5 C07D487/04 C07D471/14 A61K31/495 // (C07D487/04, 241:00, 235:00) (C07D471/14, 241:00, 235:00, 221:00)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC 5 C07D A61K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 214 632 (SEARLE) 18 March 1987 cited in the application see page 5, line 8 - page 6, line 6; claims 1,7; examples 5,8,11 --- -/-	1-3,7-15
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed		
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
2 Date of the actual completion of the international search 7 December 1993		Date of mailing of the international search report 20.12.93
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016		Authorized officer Alfaro Faus, I

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>CHEMICAL ABSTRACTS, vol. 101, no. 7, 1984, Columbus, Ohio, US; abstract no. 55037b, P.C. PARTHASARATHY ET AL 'Heterocycle N-oxides: Part II. Syntheses of new ring systems N-oxides of dihydroimidazo- and pyrimido(2,1-h)pteridines and azadihydroimidazo and pyrimido(1,2-a)quinoxalines and their antiprotozoal activities.' page 618 ; see abstract and 11th collective index, page 34074, column 1, lines 78 - 85 & INDIAN J. CHEM., SECT. B 1983, 22B(12),1233-5</p> <p>---</p>	8,14
X	<p>CHEMICAL ABSTRACTS, vol. 101, no. 7, 1984, Columbus, Ohio, US; abstract no. 55038c, P.C. PARTHASARATHY ET AL. 'Heterocyclic N-oxides: Part I . Syntheses of 1,2-dihydroimidazo(1,2-a)quinoxaline 5-oxides and 2,3-dihydro-1H-pyrimido(1,2-a)quinoxaline 6-oxides and their antiprotozoal activity' page 618 ; see abstract and 11th collective index, page 34098, column 2, lines 100,101 and column 3, lines 1-3,15-20,25-27 & INDIAN J. CHEM., SECT. B 1983, 22B(12) 1250-1</p> <p>---</p>	14
P,X	<p>WO,A,93 00900 (BRITISH TECHNOLOGY GROUP) 21 January 1993 cited in the application see claims 1-18</p> <p>-----</p>	16

formation on patent family members

International Application No
PCT/GB 93/01950

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